Modelling carbon and water fluxes in mountain ecosystems

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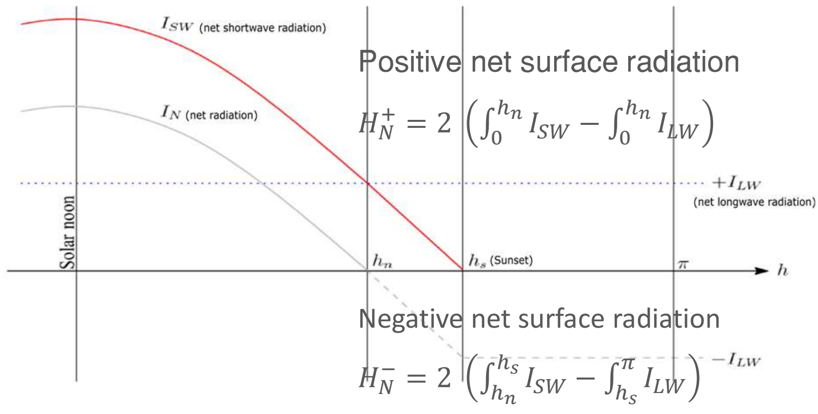
Introduction

Mountain ecosystems, with their complex environmental gradients, shallow soils, defined drainage paths and practically impervious bedrock provide an opportunity to test new modelling approaches. To achieve high spatial resolution, without inflation of computational demand, we propose analytical, rather than numerical solutions for many processes, where, to reduce the number of parameters we merged different ideas and conceptualizations. Here we present our preliminary results of simulations for water fluxes and GPP using public available datasets.

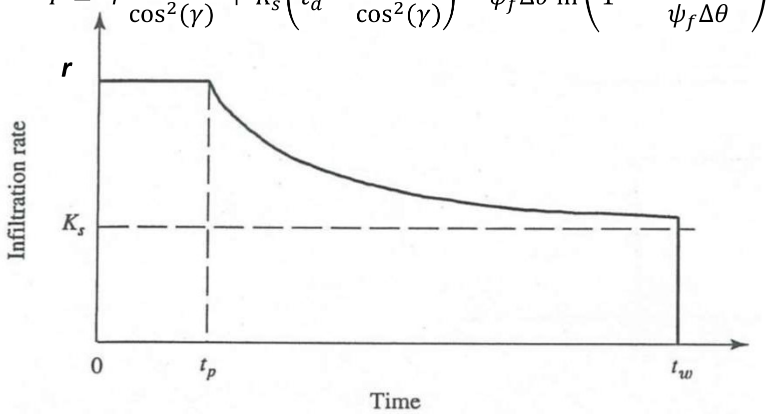
Methods

Net Radiation conceptualization, after Davis et al. (2017), terrain effects from Allen et al. (2006), used to define sunset hour (angle).

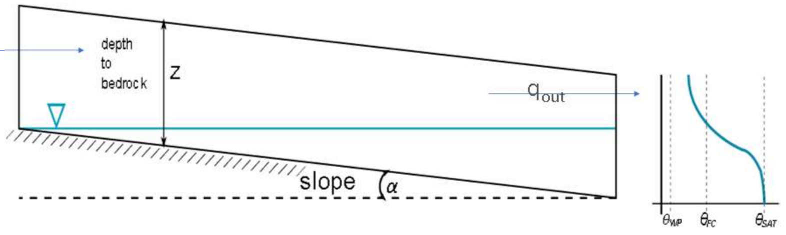


Infiltration was formulated as a Green-Ampt model, modified to reduce iterations and include ponding time. Slope corrections, after Morbidelli et al. (2018).

$$I = r\frac{t_p}{\cos^2(\gamma)} + K_s\left(t_d - \frac{t_p}{\cos^2(\gamma)}\right) - \psi_f \Delta\theta \ln\left(1 - \frac{r\frac{t_p}{\cos^2(\gamma)}}{\psi_f \Delta\theta}\right)$$



Baseflow was conceptualized using the continuity eqn. from TOPMODEL (Beven & Kirby 1979), and solving the profile transmittance using the theory from Brooks & Corey (1964).



$$T = \int_0^z K(\theta,z)dz = \frac{K_S\psi_b}{3\lambda+1}\left[\left(\frac{\psi_b}{\psi_m}\right)^{3\lambda+1} - \left(\frac{\psi_b}{\psi_m+z}\right)^{3\lambda+}\right]$$

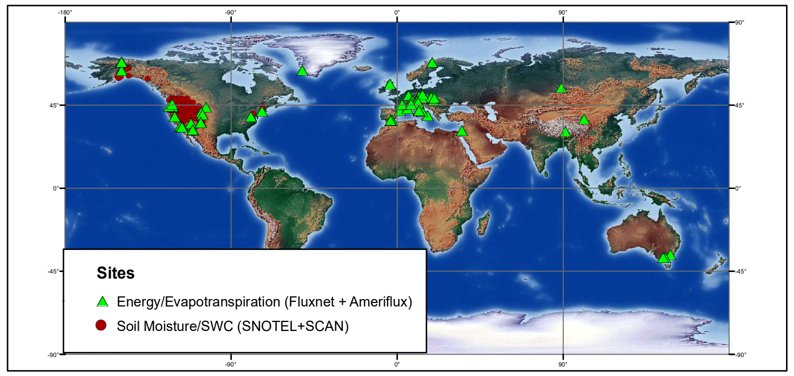
Soil Water Content in the soil profile was computed using a balance equation, while the SWC up to a specific depth z' (to allow comparisons with the measurements) was calculated using an analytical integral.

$$SWC = \int_0^{z'} \theta(z)dz = \theta_r z' + \frac{(\psi_m+z)\,(\theta_r-\theta_s)\left(\frac{\psi_b}{\psi_m+z'}\right)^{\lambda}}{\lambda-1}\Bigg|_0^{z'}$$

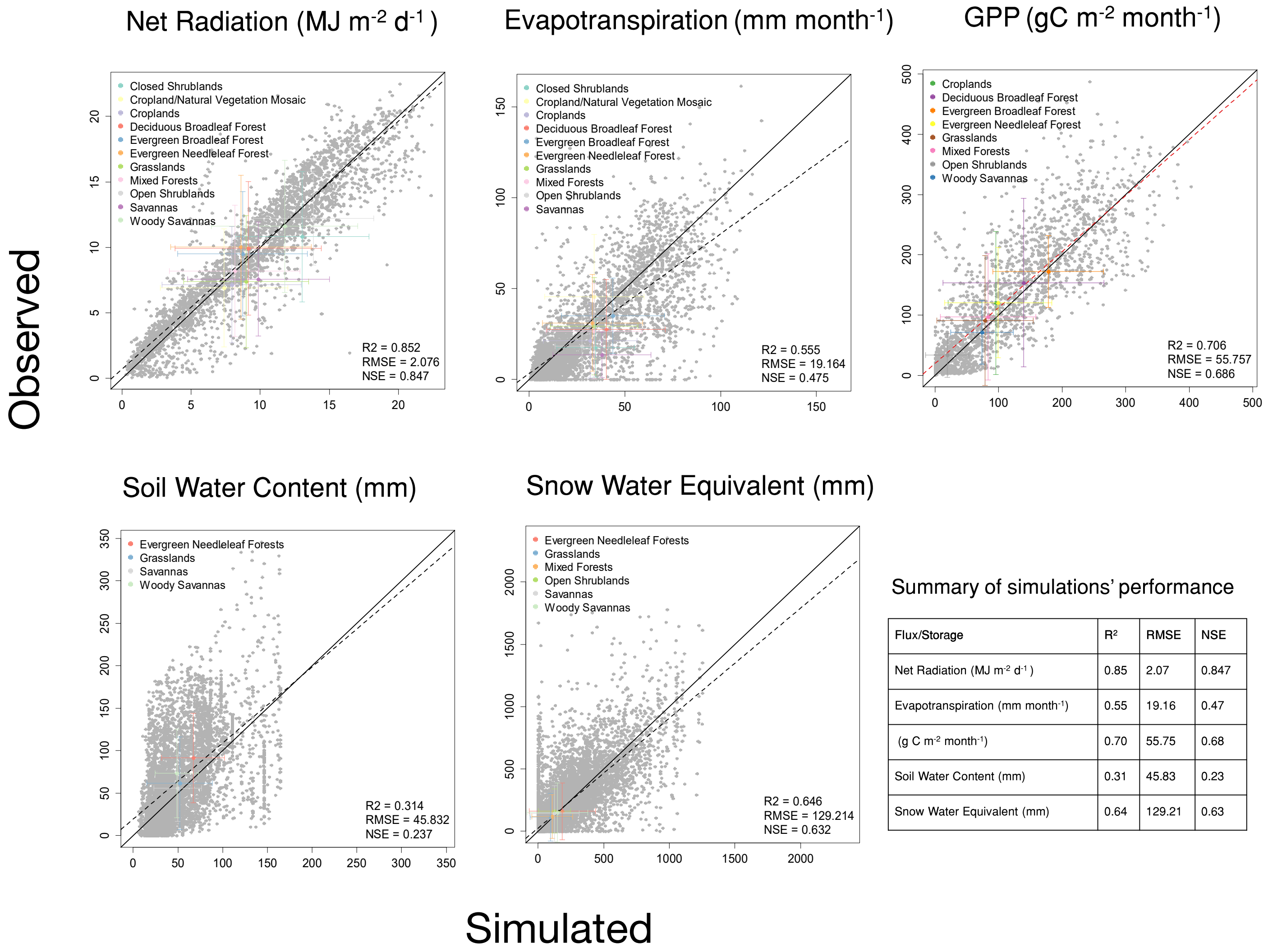
Snowfall was estimated using the approach proposed by Jennings et al. (2018), while the **snowmelt** was calculated using the energy balance.

Primary production was calculated using a model based on optimality concepts, the P-model (Wang et al., 2017), with corrections for soil moisture availability, after Stocker et al. (2018).

To **force** and **test** our model, data from several flux-towers, and monitoring networks were used, we chose sites meeting the criteria proposed by Kapos et al. (2000) to define mountain regions.



Results



Summary of simulations' performance

Flux/Storage	R^2	RMSE	NSE
Net Radiation (MJ m^{-2} d^{-1})	0.85	2.07	0.847
Evapotranspiration (mm $month^{-1}$)	0.55	19.16	0.47
(g C m^{-2} $month^{-1}$)	0.70	55.75	0.68
Soil Water Content (mm)	0.31	45.83	0.23
Snow Water Equivalent (mm)	0.64	129.21	0.63

Conclusions and further work

- Our simple assumptions and theoretical approach showed a decent agreement with the observations. Merging ideas from different models, aiming to balance complexity and robustness, will reduce the risk of obtaining "right answers for wrong reasons".
- Coupling the hydrology from the present model to a primary production model (p-model) to explore ideas on soil moisture limitation, root water uptake and transpiration.

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